II. *A description of a microscopic doublet. By* WILLIAM HYDE WOLLASTON, *M.D. F.R.S. &c.*

Read November 27, 1828.

THE state of my health induces me to commit to writing, rather more hastily than I have been accustomed to do, some observations on microscopes; and I trust, that in laying them before the Royal Society, they will meet with that indulgence which has been extended to all my former communications.

In the illumination of microscopic objects, whatever light is collected and brought to the eye, beyond that which is fully commanded by the object-glasses, tends rather to impede than to assist distinct vision.

My endeavour has been, to collect as much of the admitted light as can be done by simple means, to a focus in the same plane as the object to be examined. For this purpose I have used with success a plane mirror to direct the light, and a plano-convex lens to collect it; the plane side of the lens being towards the object to be illuminated.

With respect to the apparatus for magnifying, notwithstanding the great improvements lately made in the construction of microscopes, by the introduction of achromatic object-glasses, and the manifest superiority they possess over any single microscope, in the greater extent of field they present to view at once, whereby they are admirably adapted to make an entertaining exhibition of known objects, hardly any one of the compound microscopes which I have yet seen, is capable of exhibiting minute bodies with that extreme distinctness which is to be attained by more simple means, and which is absolutely necessary for an original examination of unknown objects.

My experience has led me to prefer a lens of a plano-convex form, even when made of glass; but the sapphire lens of this form, recently introduced into use by Mr. PRITCHARD, has a decided superiority over every single lens hitherto employed.

The cost, however, of such a lens in comparison with glass, as well as the readiness with which any number and variety of the latter kind can be procured, led me to consider what simple combinations of them might perhaps equal the sapphire lens in performance, without great cost, or difficulty of construction; and though both Mr. Herschel and Professor Airy have recently applied their superior talents to the analytical investigation of this subject, it seemed not impossible that the more humble efforts of a mere experimentalist, might be rewarded by some useful results.

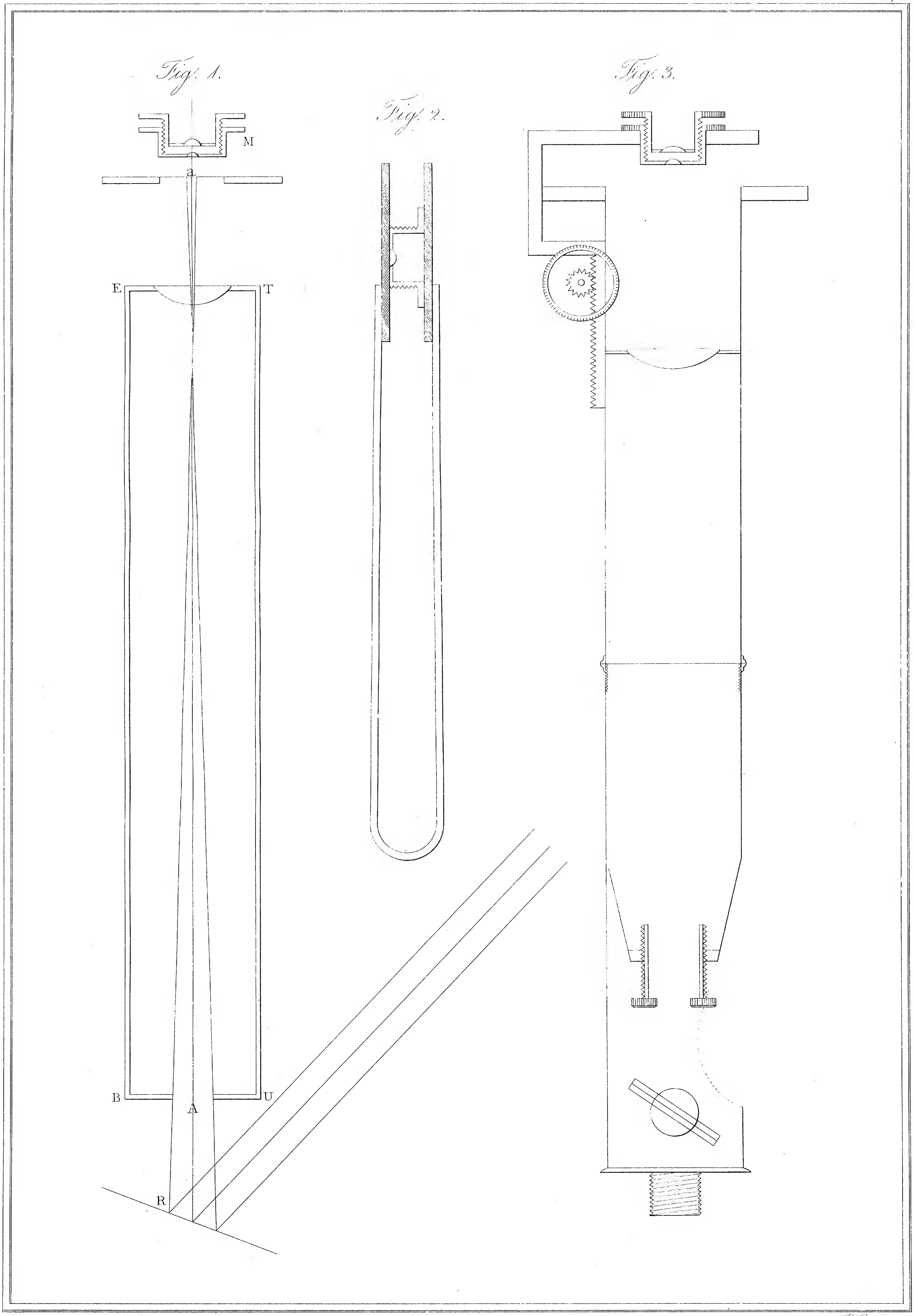
The consideration of that form of eye-piece for astronomical telescopes called Huygenian, suggested the probability that a similar combination should have a similar advantage, of correcting both chromatic and spherical aberration, if employed in an opposite direction as a microscope.

The construction which I found convenient in my trials, may be not unaptly compared to two thimbles fitted one within the other by screwing, and each perforated at the extremity. By this construction, two suitable plano-convex lenses fixed in these perforations, may, because of their plane surfaces, have their axes easily placed in the same line; and their distance from each other may be so varied, by screwing, as to produce the best effect of which they are susceptible.

As far as my trials have hitherto gone, I am led to consider the proportion of 3 to 1 as nearly the best for the relation of the foci of these lenses; and their joint performance to be the most perfect, when the distance between their plane surfaces is about $1\frac{4}{10}$ of the shorter focus. But as all the lenses I possess are not similar segments of spheres, or of the same relative thickness, I could not expect exact uniformity in the results.

The following is a description of the apparatus which I have employed.

T, U, B, E, (Plate II. fig. 1.) represents a tube about six inches long, and of such a diameter as to preclude any reflexion of false light from its sides; and the better to insure this, the inside of the tube should be blackened. At the top of the tube, or within it, at a small distance from the top, is placed either a plano-convex lens E, T, or one properly crossed, so as to have the least aberration, about three-quarters of an inch focus, having its plane side next the object to be viewed; and at the bottom is a circular perforation A, of about three-tenths of an inch diameter, for limiting the light reflected from the plane



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mirror R, and which is to be brought to a focus at *a*, giving a neat image of the perforation A at the distance of about eight tenths of an inch from the lens E, T, and in the same plane as the object which is to be examined. The length of the tube and the distance of the convex lens from the perforation may be somewhat varied. The length here given, six inches, being that which it was thought would be most convenient for the height of the eye above the table. The diameter of the image of the perforation A, need not, excepting with lower powers than are here meant to be considered, exceed one-twentieth of an inch.

The intensity of illumination will depend upon the diameter of the illuminating lens, and the proportion of the image to the perforation, and may be regulated according to the wish of the observer.

The compound magnifier M, consists, as before mentioned, of two plano-convex lenses; the proportion of the foci of these lenses being about as 3 to 1. They are fixed in their cells, having their plane sides next to the object to be viewed, their plane surfaces being distant from each other about $1\frac{4}{10}$ or $1\frac{1}{2}$ of the length of the shorter focus. This distance should be varied by trial, until the utmost possible degree of distinctness has been attained, not only in the centre, but throughout the whole field of view.

In order to determine the distance between the plane surfaces of the lenses, I have used the following contrivance. A wire (Plate II. fig. 2.) is bent so as to form a spring, to the ends of which two small pieces of plane glass are attached. Between the surfaces of the pieces of glass is placed, in the manner represented in the plate, the interior cell, or that which carries the lens of the longer focus; and the distance between the exterior surfaces of the pieces of glass is to be measured with a pair of callipers: the cell is then to be screwed into its place, and the compound cell subjected to the same operation; when the increase of distance between the exterior surfaces of the pieces of glass will evidently be equal to the distance between the plane surfaces of the lenses.

The exterior cell of the compound magnifier should be formed with a flanch, so that it may rest upon the piece that receives it. This is a far more convenient method than screwing, and the magnifiers can be more readily changed.

The lens E, T, or the perforation A, should have an adjustment by which the distance between them may be varied, and the image of the perforation be thus

brought into the same plane as the object to be examined. This may perhaps be most conveniently done by two tubes screwing one into the other.

A stage for carrying the object, furnished with the requisite means for lateral adjustments, is fixed at *a*, between the magnifier and the lens E, T. The adjustment for distinct vision is applied to the piece carrying the compound magnifier.

For the perfect performance of this microscope, it is necessary that the axes of the lenses and the centre of the perforation A, should be in the same right line. This may be known by the image of the perforation being illuminated throughout its whole extent, and having its whole circumference equally well defined. For illumination at night, a common bull's-eye lanthorn may be used with great advantage.

With this microscopic doublet I have seen the finest striæ and serratures upon the scales of the Lepisma and Podura, and the scales upon a gnat's wing, with a degree of delicate perspicuity which I have in vain sought in any other microscope with which I am acquainted.

Before I conclude, I would point out one great advantage that has confirmed me in the preference I have given to the use of a plano-convex lens, properly employed; that is, having its plane side next to the object: namely, that if such a lens should touch a fluid under examination, the view is not only not impaired, but even improved by the contact of the two media; but if a double convex lens be used, and it should accidentally touch the fluid, which not unfrequently happens when the lens is of short focus, there is an end of the examination, until the lens has been taken out, wiped, and replaced.

London,
October 28*th*, 1828.

Appendix.

The instrument which has been described will of course admit of many varieties of form; I shall, however, add a description of that which has appeared to me to be convenient, and which is represented at Plate II. fig. 3. A tube of sufficient length and diameter forms the body of the instrument; one

end of the tube is closed by a piece having a screw, by means of which it may be fixed in the top of the box intended to contain the instrument, which thus forms a support. A portion of the tube above this piece is cut away, as marked by the dotted line, for the purpose of admitting light to the small mirror which is attached to an horizontal axis passing through the diameter of the tube. The inclination of this mirror may be varied by means of a milled head fixed to the axis on the outside of the tube; the other adjustment at right angles being made by turning the box of the microscope.

Into the tube above the opening a conical piece is soldered, into which is screwed a small cylindrical tube carrying the perforation before described. The plano-convex lens is fixed in a spring tube, which slides into that which forms the body of the microscope. The position, consequently, of the lens may be varied so as to bring the image of the perforation into the same plane with the object to be viewed. A piece of plate glass about two inches square, or less if it be thought more convenient, is attached to the top of the tube, and serves to support a stage having lateral adjustments at right angles to each other. The piece into which the magnifiers fit, may be moved by a rack and pinion, and great care must be taken to arrange this adjustment, so that the magnifier may move precisely in the prolongation of the axis of the tube. The tube is divided into two pieces, of equal lengths, which screw into each other, and which when taken asunder will allow of the whole instrument being packed in a box about four inches square.

Supposing the plano-convex lens to be placed at its proper distance from the stage, the image of the perforation may be readily brought into the same plane with the object, by fixing temporarily a small wire across the perforation with a bit of wax, viewing any object placed upon a piece of glass upon the stage of the microscope, and varying the distance of the perforation from the lens by screwing its tube until the image of the wire is seen distinctly at the same time with the object upon the piece of glass.